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Estimation of catches and fate of edible bycatch species taken in the equatorial purse seine fishery

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Executive Summary

Background

This working paper responds directly to the request made at SC7 in the Ecosystem and Bycatch Theme:

> "SC7 noted the importance of food security issues and that these be considered in the strategic research plan of the SC. It was suggested that the starting points be:
>
> a) A preliminary assessment of the volumes of food fish discarded in regional tuna fisheries, especially in tropical fisheries near developing states (conducted by an agency such as SPC), and;
>
> b) a proposal for the WCPFC to look further at the impact of tuna fishing on key food stocks, noting that Resolution 2005-03 identified mahi mahi, rainbow runner and wahoo as important for sustainable livelihoods."

Analysis

This paper uses ROP observer data and delta-lognormal modelling approaches to estimate the potential level of key finfish (non-tuna) bycatch in the equatorial tuna fishery over the period 2000-2011. It also examines the potential fate of that bycatch.

Results

- Purse seine sets associated with FADs and other floating objects result in an on average higher catch rate of non-billfish species, in particular rainbow runner and dolphinfish, and a slightly higher bycatch catch rate overall.
- By comparison, catch rates of billfish, in particular blue and black marlin, were higher in unassociated sets. Combined billfish species ('BIL') were twice as common by weight in unassociated sets compared to associated sets.
- Catch rates were raised by the level of effort by set type over time. The greatest total bycatch of the species examined was estimated in 2011, with peaks in the estimated catches of rainbow runner and high estimated catches of key billfish species. Mean bycatch estimates in 2011 across the species examined totalled 996 mt. Approximately 50% of this was rainbow runner.
- The subsequent fate of bycatch species was summarised into three groups: 'retained'; 'discarded' (alive or dead) and 'other' (unknown or escaped). Over 50% of the catches of each species were discarded from both set types, the exceptions being sailfish and wahoo where the majority of catches were retained.
- The proportional fate of a species was generally consistent between set types.
- It should be noted that the estimates presented herein are preliminary, and a number of areas for improvement in modelling approaches are noted (below).

Next steps

Areas for consideration within a food security-focused research plan are suggested. These include:

- Improving our understanding of the practical reasons behind the pattern of discarding by purse seine vessels.
- An understanding of the finer spatial pattern of bycatch, relative to the location of unloading ports.

Areas of technical development for future analyses are also suggested.

Introduction

The Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean text notes 'the need to avoid adverse impacts on the marine environment, preserve biodiversity, maintain the integrity of marine ecosystems and minimize the risk of long-term or irreversible effects of fishing operations on ecosystem'. To this aim, Part II Article 5 notes the need to 'assess the impacts of fishing, other human activities and environmental factors on target stocks, non-target species, and species belonging to the same ecosystem or dependent upon or associated with the target stocks'.

Purse seine operations do not result in a 'clean' catch of tuna species alone. Other commercial and non-commercial species will be caught that must then either be retained for sale or consumption on board, or discarded. In turn, the level of bycatch is likely to vary between the type of set performed (associated with FADs and other floating objects, or those on free school tuna aggregations) as well as the geographic location of fishing.

The 'bycatch' of 'non-target' tuna species by set type has been studied in considerable detail, while catch figures for billfish are regularly included in Scientific Committee information papers (ST-IP-01; OFP, 2011). In turn, shark bycatch in purse seine fisheries has been the subject of separate focused analyses (e.g. SC7-EB-IP-02), while analyses of the patterns of wider bycatch have been performed based on a number of data sources (e.g. Lawson, 1997; Harley et al., 2011).

The recent changes in the equatorial purse seine fishery, including implementation of FAD fishing bans in particular months of the year, may impact on levels of non-target bycatch. If retained onboard, this bycatch may represent a source of potential cheap protein for Pacific communities, important for food security. However, there is uncertainty on the degree of 'edible' bycatch that may arise from the equatorial purse seine fishery. This paper provides preliminary estimates of the potential level of finfish (non-tuna) bycatch in the tropical WCPFC-CA over the recent period (2000-2011), along with their potential fate.

Data analysed

WCPFC Regional Observer Programme records provide the most comprehensive data set available on the level of bycatch species caught by purse seiners within the tropical WCPFC-CA. Eight main non-tuna finfish species were examined within the current analyses (Table 1). These species represent the most common species noted by observers across the study period. For the analysis, billfish species (black, blue and striped marlin, and sailfish) were also combined into a total billfish category ('BIL').

Table 1. Non-tuna finfish bycatch species examined within the current analyses.

Species code	Common name	Scientific name
BAR	Barracudas	*Sphyraena spp.*
BLM	Black marlin	*Istiompax indica*
BUM	Blue marlin	*Makaira nigricans*
DOL	Dolphinfish	*Coryphaena hippurus*
MLS	Striped marlin	*Kajikia audax*
RRU	Rainbow runner	*Elagatis bipinnulata*
SFA	Sailfish	*Istiophorus platypterus*
WAH	Wahoo	*Acanthocybium solandri*

Observer data on species catch levels and frequencies were extracted at a set-by-set level for the period 2000 to 2011 inclusive.

Catch rates

In a high proportion of sets, no bycatch of a species under consideration was noted by observers ('zero catch' sets; Table 2). To take into account the high proportion of 'zero-catch' sets, two separate GLMs were fitted to the species catch-per-set using a delta-lognormal GLM approach (Lo et al., 1992). The proportion of tows where the species was present in the catch was modelled with a binomial error distribution:

$$Species\_present_{i,j} \sim Year_i * Set\_type_j$$

where i = 2000-2011, and j=associated or unassociated set.

The level of the catch rate (catch per set) in those sets where a species was caught (positive sets) was modelled assuming a lognormal error distribution:

$$Ln(Species\_catch)_{i,j} \sim Year_i * Set\_type_j$$

where i = 2000-2011, and j=associated or unassociated set.

Based upon the model estimates for each species, an average catch rate by year and set type was developed from the product of the two model predictions (generated using the predict.glm function in R), with bias correction applied to the lognormal estimates. A measure of the variance around these estimates (standard errors) was obtained directly from the GLM prediction.

An average catch rate (kg/set) estimate for each species within the purse seine fishery across the period 2007-2011, representing the last 5 years, by set type (‘associated’ sets and ‘unassociated’ sets) is presented in Table 2.

Table 2. Proportion of 'zero catch' sets and mean catch rates (kg/set) of key bycatch species in purse seine sets by set type across the period 2007-2011, across those areas of the tropical WCPFC-CA where observer information was available.

Species	Code	Proportion of observed sets with zero catch[1]	Catch rate (kg/set)	
			Associated sets	Unassociated sets
Barracuda	BAR	0.99	0.269	0.117
Total billfish	BIL	0.97	2.983	9.043
Black marlin	BLM	0.99	0.829	2.888
Blue marlin	BUM	0.98	1.501	4.873
Mahi mahi	DOL	0.97	2.370	0.497
Striped marlin	MLS	1.00	0.542	0.929
Rainbow runner	RRU	0.92	16.226	2.123
Sailfish	SFA	1.00	0.071	0.230
Wahoo	WAH	0.98	0.728	0.134
Total			**25.519**	**20.834**

[1] to two decimal places

Purse seine sets associated with FADs and other floating objects result in an on average higher catch rate of non-billfish species, and a slightly higher bycatch catch rate overall. In particular, the average catch rate of rainbow runner over the 5 year period in associated sets was eight times that in unassociated sets. This is clearly observed in Figure 1, which presents the average bycatch catch rates for 2011 only, as an example. Catch rates of dolphinfish were also notably higher in associated sets. In contrast, catch rates of billfish, in particular blue and black marlin, were higher in unassociated sets. Combined billfish ('BIL') were twice as common by weight in unassociated sets compared to associated sets.

There was considerable inter-annual and between-set variability in the average bycatch rate. For example, the mean catch rate for rainbow runner in 2010 (23.8kg/set in associated sets) is notably higher than the mean over the 2007-2011 period presented in Table 2 for that species (16.2 kg/set).

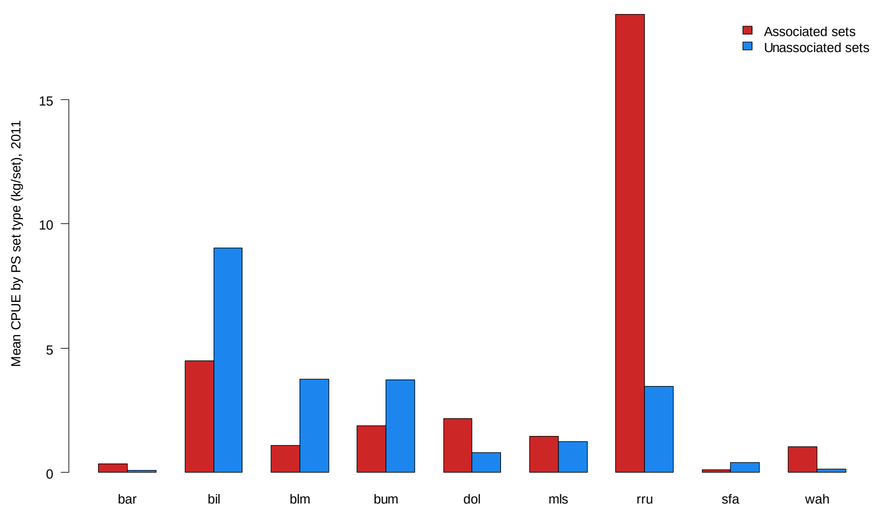


Figure 1. Mean catch rates of species and species groups within the tropical WCPFC-CA by purse seine set type, in 2011.

Effort levels

Total annual effort by set type for the tropical WCPFC-CA region was developed from purse seine effort information, raised to EEZ-level annual catch estimates where necessary. These data were extracted for the period 2000-2011 to correspond with the available observer information, between 20°N and 20°S within the WCPFC-CA, excluding Indonesian and Philippines domestic purse seine fleets (Figure 2).

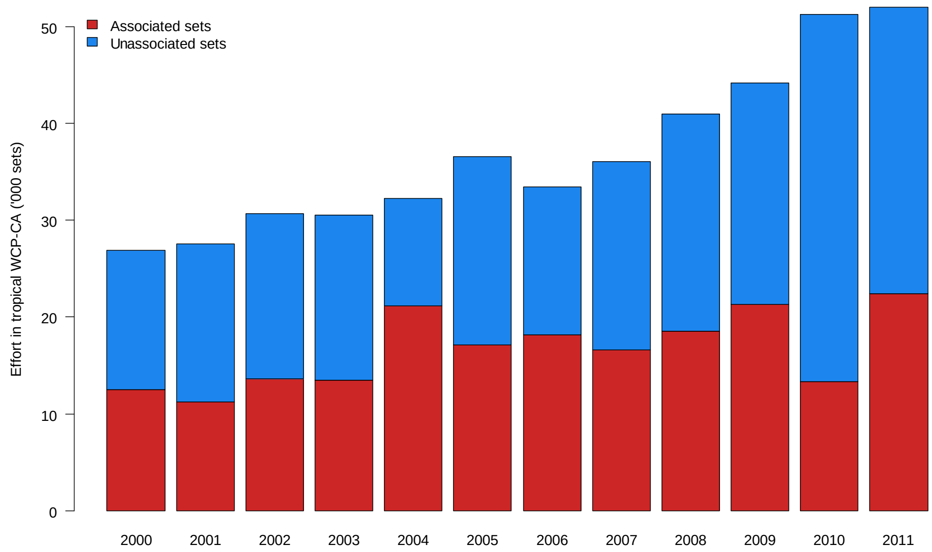
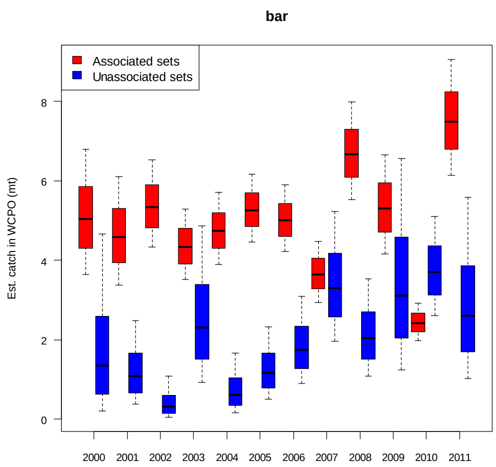


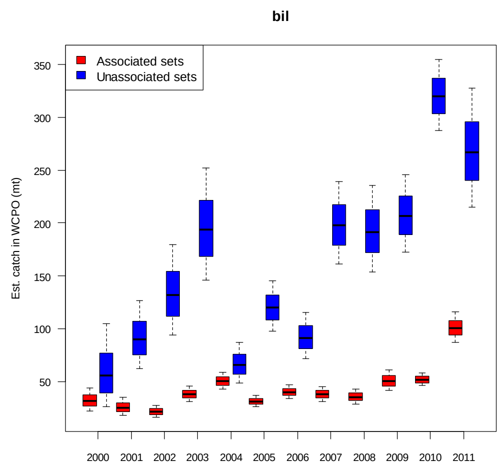
Figure 2. Level of effort (sets) by year and set type within the tropical WCPFC-CA (excludes Indonesian and Philippines domestic purse seine fleets).

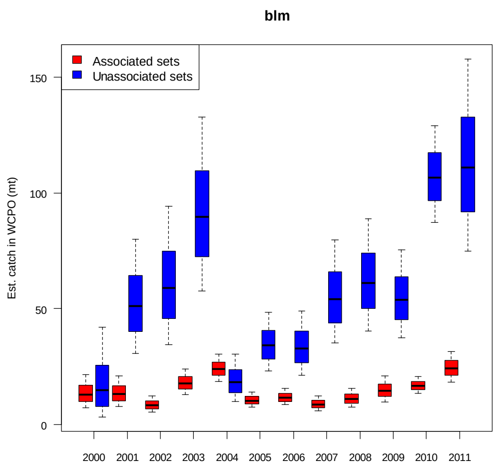
There is a general increasing trend in the number of purse seine sets in the tropical WCPFC-CA since 2000. The proportion of associated and unassociated sets per year has generally been comparable. An exception is 2010, where the fishery showed a significantly greater proportion of sets on free schools, commensurate with the different behaviour of vessels around the 3 month FAD-closure in that year. This shift is seen to a lesser extent in 2011.

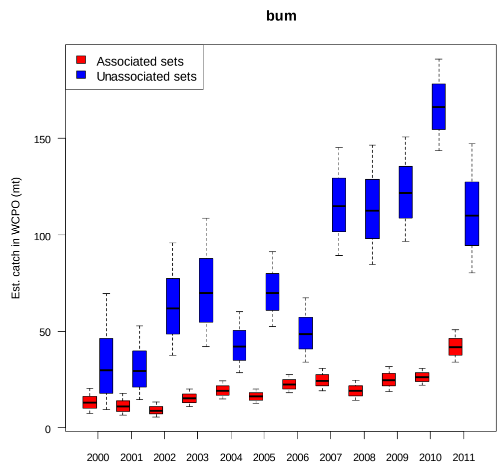
Total catch estimates

To identify the level of catch by year and set type, and the variability in potential bycatch catch weight estimates for the tropical WCPFC-CA, the GLM model estimates for species average catch rate by year and set type were multiplied by the number of sets of each type in that year (see Figure 2). The variance around the GLM model predictions were used to provide an estimate of the 95% confidence intervals around the mean catch estimates. Table 3 presents the resulting annual mean estimated catches by species and species group, while Figure 3 presents the time series mean catch estimates by species and species group over time.


bar
Associated sets
Unassociated sets
Est. catch in WCPO (mt)
0
2
4
6
8
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


bil
Associated sets
Unassociated sets
Est. catch in WCPO (mt)
50
100
150
200
250
300
350
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


blm
Associated sets
Unassociated sets
Est. catch in WCPO (mt)
0
50
100
150
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


bum
Associated sets
Unassociated sets
Est. catch in WCPO (mt)
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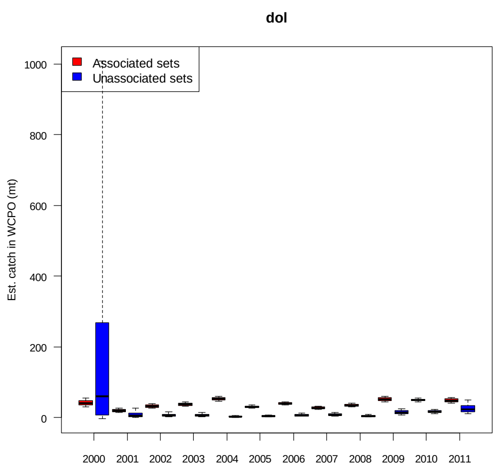
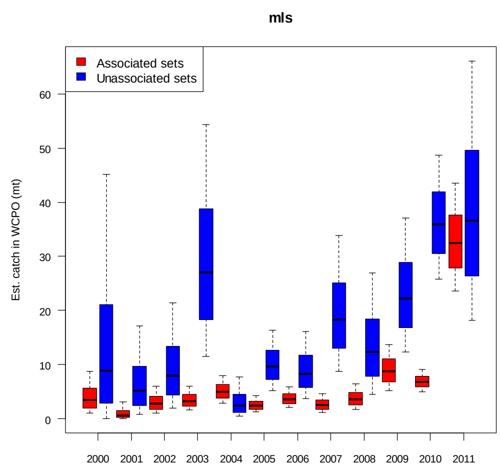
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


dol
Associated sets
Unassociated sets
Est. catch in WCPO (mt)
0
200
400
600
800
1000
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


mls
Associated sets
Unassociated sets
Est. catch in WCPO (mt)
0
10
20
30
40
50
60
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

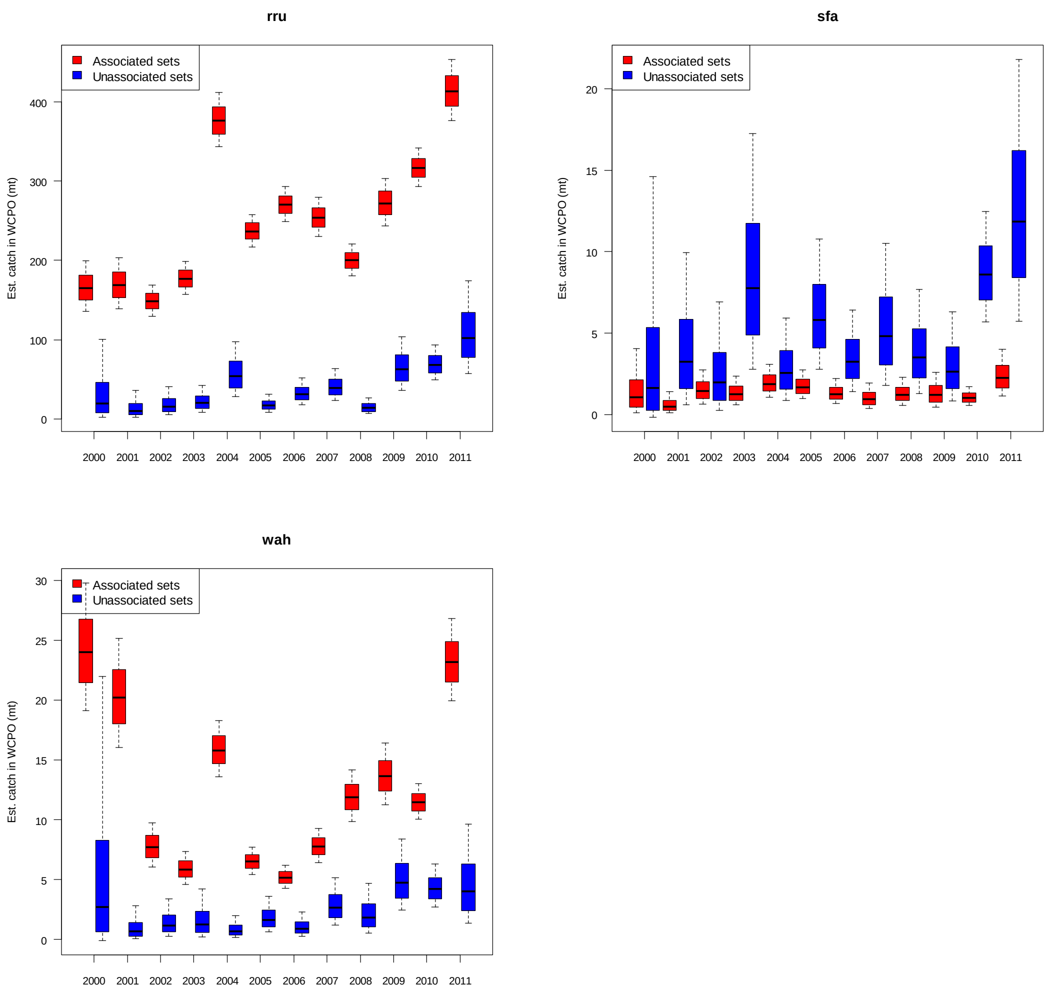


Figure 3. Total catch of each species and species group (mt) by year and set type for the period 2000-2011. Whiskers represent the 95% confidence interval range of the mean catch estimate of each species (extreme values therefore not presented). Note the different scales on the y-axis of each graph.

The greatest total bycatch of the species examined was estimated in 2011, with relatively high bycatch of key billfish species, and a peak in the estimated catch of rainbow runner (around 50% of the estimated total catch; Table 3).

Following the pattern seen in the CPUE, non-billfish catches were estimated to be higher in associated sets, and by comparison lower in unassociated sets. The highest bycatches were estimated for rainbow runner, with catches peaking in associated sets in 2011 (driven by estimated high catch rates in that year) with high mean total catches above 400mt in 2004, and increasing from over 200 mt in 2008 to the 2011 peak. For dolphinfish, the next most common non-billfish bycatch species, the highest estimate was generated in 2000, where some unusually high catch rates, up to 10 mt per set, were apparently observed. For other non-billfish finfish bycatch species (barracuda and wahoo), estimated mean catches were below 30 mt per year.

Billfish catches generally increased over time, in particular since 2004. Estimated catches peaked in 2010, with nearly 380 mt of all billfish species combined ('BIL'), and nearly 350 mt of that coming from unassociated sets (Table 3, Figure 3). The most common billfish species were estimated to be blue and black marlin ('BLM' and 'BUM'). Annual catches of other billfish species (striped marlin, sailfish) were estimated to be below 70 mt.

Table 3. Estimated mean total catches (mt) for each species or species group by year. Total represents the estimated weight of the individual species (excluding BIL).

	BAR	BIL	BLM	BUM	DOL	MLS	RRU	SFA	WAH	**TOTAL**
2000	6	87	28	43	102	12	185	3	27	**405**
2001	6	115	64	41	25	6	179	4	21	**345**
2002	6	153	67	71	38	11	164	3	9	**369**
2003	7	231	108	85	43	30	197	9	7	**486**
2004	5	116	42	62	56	7	430	4	17	**623**
2005	6	151	44	86	34	12	254	7	8	**453**
2006	7	131	45	71	46	12	301	5	6	**493**
2007	7	235	63	139	35	21	293	6	10	**575**
2008	9	227	72	132	39	16	214	5	14	**500**
2009	8	257	69	146	67	31	335	4	18	**678**
2010	6	372	123	193	67	43	385	10	16	**841**
2011	10	368	135	152	72	69	516	14	27	**996**
Average	**7**	**204**	**72**	**102**	**52**	**23**	**288**	**6**	**15**	**564**

Fate of bycatch species

The observer database provides an indication of the fate of each bycatch species. As an observer is often unable to monitor the fate of all bycatch species due to other duties, this 'bycatch fate' dataset represents a reduced coverage compared to that examined for the analysis presented above.

The available information on fate was summarised into three broad categories by species and species group, being: 'retained'; 'discarded' (alive or dead) and 'other' (unknown or escaped). The proportion of the weight of each species falling into each fate category was calculated by year and set type (Table 4, Figure 4).

Table 4. Observed proportional fate of each species (by weight) in the tropical WCPFC-CA averaged over the period 2007-2011

	Associated sets			Unassociated sets		
	Discarded	Retained	Other	Discarded	Retained	Other
BAR	0.42	0.58	0.00	0.84	0.16	0.00
BIL	0.57	0.43	0.00	0.62	0.38	0.00
BLM	0.55	0.45	0.00	0.56	0.44	0.00
BUM	0.60	0.39	0.00	0.66	0.33	0.00
DOL	0.64	0.36	0.00	0.76	0.24	0.00
MLS	0.51	0.49	0.00	0.67	0.33	0.00
RRU	0.75	0.25	0.00	0.74	0.26	0.00
SFA	0.37	0.63	0.00	0.31	0.69	0.00
WAH	0.46	0.54	0.00	0.23	0.77	0.00

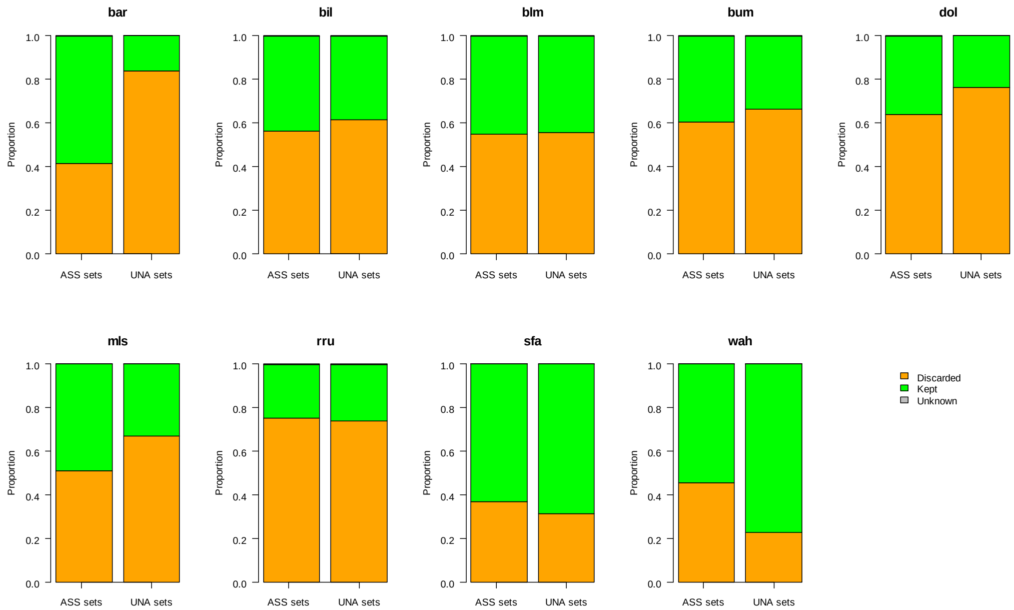


Figure 4. Proportional fate of those individuals (by weight) caught in associated (ASS) and unassociated (UNA) sets, by species, over period 2007-2011.

Over 50% of the catches of each species were discarded from both set types, the exceptions being sailfish and wahoo, where the majority of these small bycatches were retained (see also Figure 5). Nearly three quarters of the rainbow runner bycatch, and a high proportion of the dolphinfish bycatch, were discarded. For the majority of species, there was consistency in the patterns of discarding and retention between set types. The exceptions were for barracuda, where a higher proportion of individuals were observed as discarded when caught in unassociated sets, and to a lesser extent wahoo, where the opposite pattern was observed.

Using the mean estimates of annual catch presented in Table 3 and the average proportional fates presented in Table 4, the weight of each species meeting a particular fate was estimated by year and set type (Figure 5), and summarised for 2011 in Table 5.

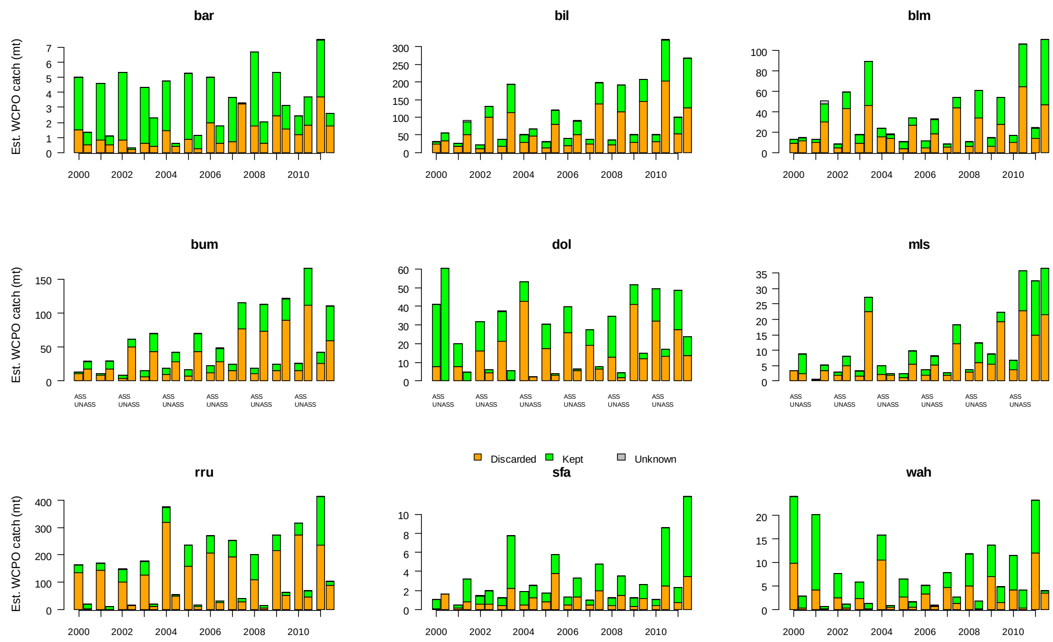


Figure 5. Estimated catch of each species in associated and unassociated sets (paired bars), by year, and their subsequent fate.

The variation in estimated annual catch levels of each bycatch species and the contrasting pattern between associated and unassociated sets in billfish and non-billfish species is seen in Figure 5. Using 2011 as an example (Table 5), of the estimated mean 996 mt of total bycatch of examined species in that year, 58% was discarded.

Table 5. Mean weight (mt) of each species meeting each fate across all set types, estimated for the year 2011 as an example. Fate estimate rounded to the nearest mt.

	Discarded	Retained	Other
BAR	5	5	0
BIL	180	188	0
BLM	61	74	0
BUM	85	67	0
DOL	41	31	0
MLS	36	33	0
RRU	325	191	0
SFA	4	10	0
WAH	15	12	0
TOTAL (not incl. 'BIL')	**573**	**422**	**0**

Next steps

This study provides a preliminary examination of the potential catch of non-target finfish species in the equatorial purse seine fishery in recent years, and begins to address the first element of the SC7 request.

The general increases seen in estimated bycatch levels may in part be due to the increases in activity within the tropical WCPFC-CA purse seine fleet. However, they may also be related to increased coverage of those activities by observers in recent years. The further increased observer coverage of the purse seine fleet in the coming years should lead to improved precision and reduced bias in estimates of presence/absence of species in the catch, catch rate and estimated catches of bycatch species, as well as their subsequent fate. Indeed, the potential for a 'zero-catch' set to represent an observer being unable to note any bycatch due to other duties, rather than a true absence of catch, will lead to underestimates of bycatch weight in the current analysis.

Estimates of the total catch (retained and discarded) of blue and black marlin in the current study are of a similar magnitude to, but notably lower than, commercial catches by purse seine vessels in the WCPFC-SA reported in OFP, 2011 (see Table 19 of that paper). In part this may result from the different geographic areas examined in the two papers. If the values presented in OFP (2011) represent retained catches only, applying the discard rates identified in the current paper would imply that in 2010 around 1,300 mt of blue marlin, and 620 mt of black marlin, may have been discarded.

The patterns of bycatch in FAD-associated and unassociated purse seine sets suggest that while FAD closure periods might reduce pressure on certain bycatch species, the impact on billfish species may be increased.

The basic modelling approach used here can be refined to take into account important spatial influences (e.g. Lawson, 2011) given variation in the spatial coverage of observers and pattern of purse seine catches from year to year. With respect to food security, a refined understanding of the finer spatial pattern of bycatch is needed for key species, relative to the location of unloading ports. Furthermore, improving our understanding of the reasons behind the pattern of discarding by purse seine vessels is required.

To begin addressing the second element of the SC7 request, linking the results of improved bycatch volume analyses to risk-based considerations of vulnerability (e.g. through ERA) might highlight those species for which further investigation and assessment is necessary. Monitoring of trends in species' estimated CPUE over time may focus further areas of work. Where corresponding discard estimates are considered significant, the analyses need to be combined with post-discard survival studies to better calculate potential overall mortality.

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